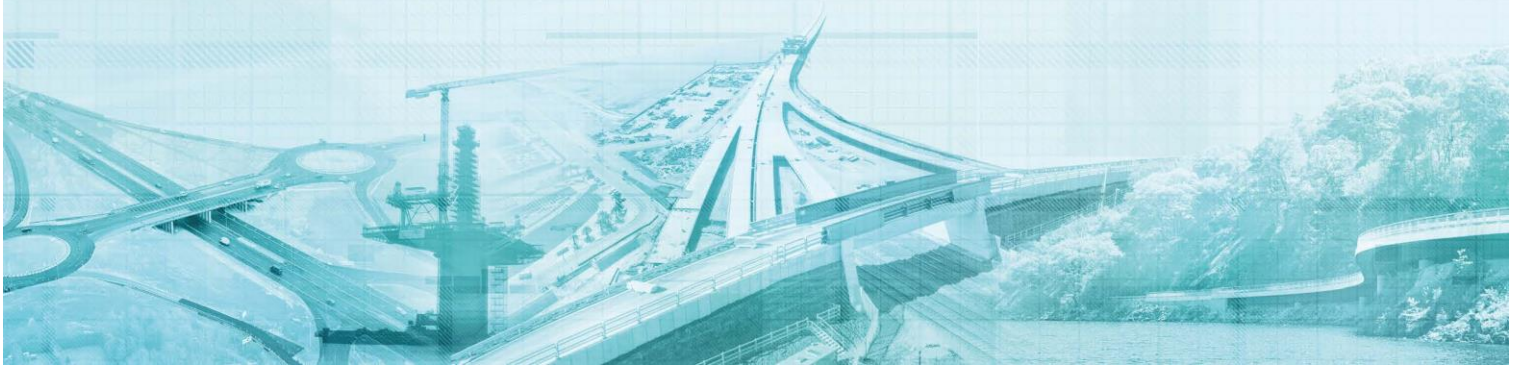
Bean Tunnel

Technical Note on the Assessment of Pipe Strains due to Ground Settlement – Bluewater Parkway

Balfour Beatty

Document no: BRT-TG-XX-ZZ-TN-UT-0001

Revision: P01 Date: 11/01/22



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Document Issue Record

Project:	Bean Tunnel
Report Title:	Technical Note on the Assessment of Pipe Strains due to Ground Settlement - Bluewater Parkway
Client:	Balfour Beatty
Document No:	BRT-TG-XX-ZZ-TN-UT-0001
Revision:	P01
Status	S3 – Suitable for Review/Comment
Date:	11/01/22
Filename:	BRT-TG-XX-ZZ-TN-UT-0001

Rev	Date	Description and Purpose of Issue	Prepared	Reviewed	Approved
P01	11/01/22	For review and comment	AJB	JR	JR

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1. Introduction

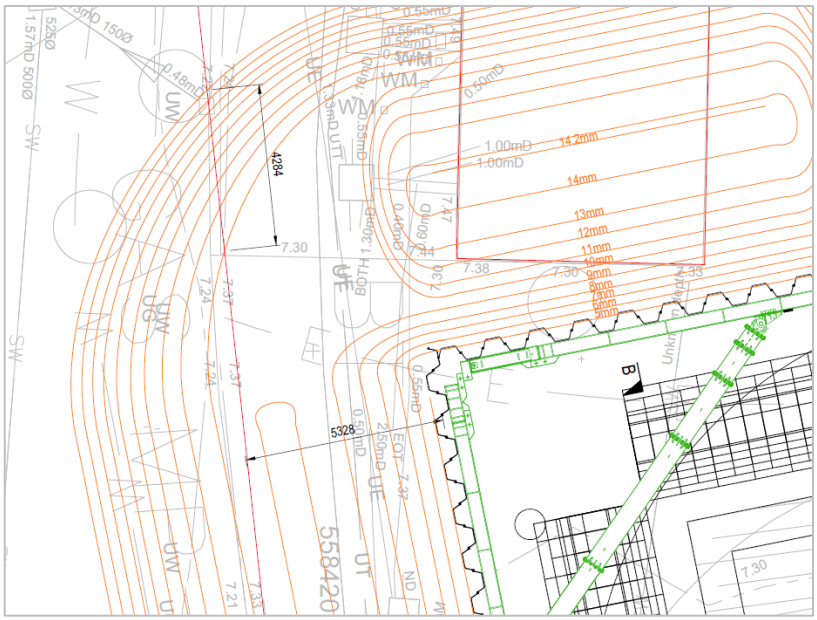
This Technical Note covers the calculation of bending and axial strains induced in a Thames Water owned pipe as a result of predicted ground settlement caused by nearby cofferdam excavation. This assessment has been carried out to discharge a Planning Condition established to protect Thames Water's assets.

2. Input information

A review of the predicted settlement contours around the cofferdam (ref Document No: CRXC0062-BBMP-00-XX-TN-W-0001 P01 Technical Note on Ground Settlement Adjacent to Proposed Cofferdam Excavation Bluewater Parkway) reveals the worst-case scenario will occur where the pipe alignment crosses a succession of contours over a short distance thus inducing curvature in the pipe due to differential settlement.

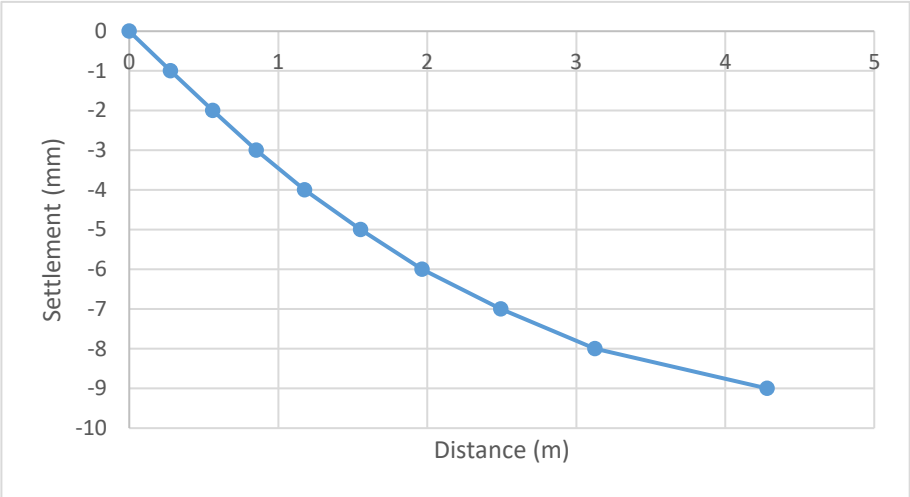
The worst-case scenario as deduced from the settlement plots occurs in the Northwest corner of the cofferdam where the greatest rate of change in level occurs. The extent of pipe chosen for assessment is 4.284m in length and is indicated by the red line in Figure 1 below.

Figure 1. Extract from Settlement Contour Plot.



According to asset information, the Thames Water pipe material is MDPE with a diameter of 355mm. Over the 4.284m assessed length, the ground settles a maximum of 9mm. The graph shown in Figure 2 below, is a representation of the ground settlement at points along the pipe according to the drawing excerpt shown above

Figure 2. Graph indicating the vertical settlement at contour intervals.



3. Idealisations and Assumptions

The assessment assumes that the pipe follows a similar settlement profile to that of the ground, albeit beneath the surface. Using the predictions of magnitude of ground surface settlement, this is considered to be conservative for assessment of the pipe itself.

No beneficial effect of cofferdam corner rigidity has been considered, which would likely reduce the predicted ground surface settlement by up to 50% in the zone of movement used in this assessment. This is considered to add an additional level of conservatism.

4. Assessment methodology

Having identified the location of the greatest rate of change, the longitudinal curvature was plotted to identify points of inflection. In the case of Figure 2 the point of maximum inflection occurs to the northern end of the longitudinal profile, within the first metre. However, a flexible pipe will tend to flex to accommodate the settlement profile rather than change direction abruptly.

When considering bending strain, the values from the graph in Figure 2 were used directly for calculation.

For axial strain calculation, two limiting conditions were considered as to whether, in trying to accommodate ground movement in this way, the structural integrity of the pipe would be compromised:

- Manufacturer's specified minimum bend radius (pink circle in Figure 3)
- Maximum radius of best fit (red circle in Figure 3)

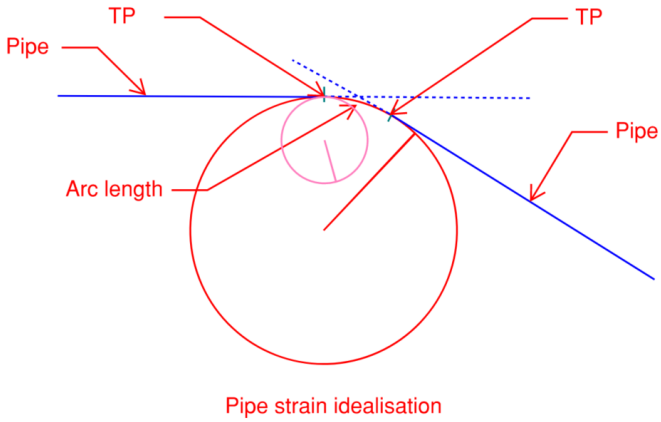


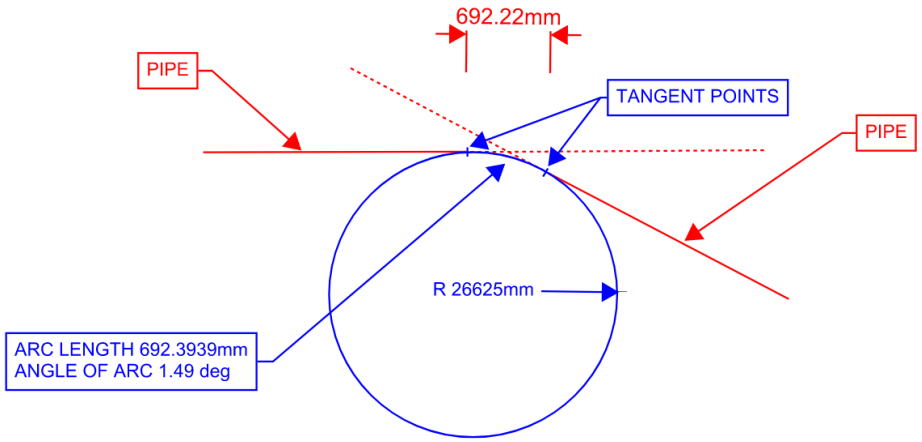
Figure 3. Diagram showing the idealisation of the curvature of the pipe – not to scale

The minimum pipe bend radius is calculated by multiplying the pipe radius by the bend ratio of the pipe material; in the case of MDPE this ratio is approximately 15. This gives a minimum bend radius of 2662.5mm.

By fitting a circle of the same radius to the settlement curve and setting it out according to a tangent point at 0mm settlement, a curve of radius 2662.5mm (minimum bend radius) results in a settlement profile which is much steeper than the predicted settlement curve, meaning the pipe is likely flexing within its allowable limits. This is represented diagramatically by the inner circle in Figure 3.

By incrementally increasing the radius of the curve one obtains a best fit radius of curvature which fits the predicted settlement profile creating a tangent point on the settlement line, whilst not crossing either line at any point. Thus, an arc described by a circle of radius 26,625mm was considered a reasonable representation of the curvature that the pipe may follow transitioning from level to inclined. See Figure 4 below for a representation of the idealisation.

Figure 4. Diagram showing best-fit circle geometry – not to scale



5. Calculations

5.1. Bending Strain

Using Figure 2, the radius of longitudinal curvature of the pipe is calculated using the following equation.

$$R_n = \delta_2 \{2 \cdot S / _{v,n} - (S_{v,n-1} + S_{v,n+1})\} \quad [i]$$

Using an interval of 0.1m between data points, the radius of longitudinal curvature is calculated to be 500,000mm. From this radius ,the bending strain was calculated to be 355 με (micro strain) using the following equation.

$$D/(2 \cdot Rn) \quad [ii]$$

5.2. Axial Strain

To calculate the axial pipe strain, measurements of the curved pipe length compared with the original length of the pipe (in the horizontal plane) were made. Accordingly , the horizontal distance is 692.22mm and the arc length is 692.393mm using the best-fit circle geometry shown in Figure 4. Using the formula below axial strain was calculated as 250.8 με.

$$Strain = \frac{\Delta\ Length}{Original\ Length}$$

5.3. Results and Acceptance criteria

Parameter	Value
Bending Strain	355 με
Axial Strain	250.8 με
Total Strain (Bending + Axial)	605.8 με
Acceptance Criteria	50,000 με[iii]

Table 1. Summary of strain values.

The combination of the bending and axial strain values gives a total strain of 605.8 με. This value can be compared with the acceptance criteria of 50,000 με for MDPE pipes (Reference no.4).

6. Conclusion

In conclusion, the total, combined pipe strain of 605.8 με lies well within the relevant acceptance criterion of 50,000 με, notwithstanding the conservatisms set out earlier in this Note. On this basis the settlements predicted due to the cofferdam do not pose a risk to the Thames Water asset.

7. References

[i] B. New (2019). Tunnel construction impacts on utility pipelines. Tunnels and Tunnelling February 2019 pp 32.
[ii] B. New (2019). Tunnel construction impacts on utility pipelines. Tunnels and Tunnelling February 2019 pp 28.

[iii] *I. Bjorklund (2001). Structural design of pressure pipes. Water Science and Technology: Water Supply Vol 1 No 3 pp 107-115).*